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TECHNICAL PROGRESS REPORT

Bell Report No. 60007-034

Quarterly Report

15 May 1969

JPL Contract No. 951492

Bell Aerospace Corporation

Bell Aerosystems Company

Cleveland, Ohio 44103

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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, as sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

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ABSTRACT

Sterilization testing of two accelerometers was concluded during this reporting period. The performance of these instruments was similar to that of the previously shipped units.

The final accelerometer is being built with a beryllium proofmass structure and specially heat treated springs.

Two laser welded proofmass assemblies are being built containing normally manufactured springs. The fifth pendulum assembly will also utilize specially heat treated flexures in an effort to improve null stability.

A transformerless pickoff electronics failed in testing due to contamination of the uA709. Otherwise, test results were satisfactory and the thermal sterilization capabilities of a bonnet of this design is promising.

ACCELEROMETERS

During the quarter ending April 30, 1969 the thermal sterilization testing of two accelerometers, serial numbers 0657 and 0660, was completed and the two instruments were shipped April 24th. The test data compiled on these two units form Tables 1, 2, 3 and 4. Evaluation of these units indicate that the bias characteristics are similar to those observed in the first two delivered accelerometers. The extended curing of the epoxy spring-to-support joint for 60 hours and the increased temperature of 300°F did not reduce the bias shift caused by the sterilization environment. The scale factor stability of the two units was again good.

In an effort to eliminate the thermal incompatibility between the aluminum pendulum and the steel base plate, the torque coil assembly of the fifth accelerometer is being built with the beryllium proofmass structure shown in Figure 1 and 2. The spring joint stresses should thereby be reduced by a factor of 40. Also to be incorporated in the fifth sterilizable accelerometer are "overaged" springs. In the standard spring manufacturing process, the maximum tensile strength of the spring material is attained by aging at 650°F for 30 minutes. Recently however, metallurgists from the Brush Beryllium Corporation have pointed out that the heat treating of the spring material for maximum tensile strength usually does not provide good form and dimensional stability.

Spring materials "overaged" at 725°F for 1½ hours should reduce the undesired mechanical hysteresis loops. This aging strategy can only be employed for alloys which gain their strength by preceipitation hardening as is the case with our CuBe spring material. Although there is a reduction in the tensile strength of the spring material, the increased microyield strength and improved microcreep prorertied anticipated for these springs should reduce the bias hysteresis due to mechanical and thermal stresses.

ACCELEROMETER S/N 0657
INITIAL TESTING

T(I)	V90(I)	V270(I)	SF(I)	MA/G	B(UG)	PPM/F	B(UG/F)
73.18	-1.047512	1.046787	1.047150	0.910565	-346.1	0.0	0.0
123.55	-1.052648	1.052487	1.052567	0.915276	-76.1	103.2	5.4
150.08	-1.055401	1.055599	1.055500	0.917826	94.0	105.0	6.4
175.06	-1.058098	1.058649	1.058373	0.920325	260.4	110.2	6.7
73.00	-1.047429	1.046758	1.047093	0.910516	-320.6	104.4	5.7
125.06	-1.052790	1.052679	1.052734	0.915421	-52.5	104.0	5.1
148.62	-1.055263	1.055470	1.055366	0.917709	98.0	106.0	6.4
175.57	-1.058105	1.058680	1.058392	0.920360	271.7	107.5	6.4
71.20	-1.047247	1.046570	1.046998	0.910355	-327.4	103.0	5.7
122.83	-1.052526	1.052428	1.052477	0.915197	-46.7	103.5	5.4
150.46	-1.055475	1.055721	1.055598	0.917911	116.5	109.2	5.9
175.69	-1.058154	1.058749	1.058452	0.920393	281.1	108.3	6.5
71.78	-1.047323	1.046630	1.046976	0.910414	-331.1	104.3	5.9
122.58	-1.052520	1.052338	1.052428	0.915155	-86.5	107.0	4.8
147.83	-1.055180	1.055366	1.055272	0.917628	88.1	107.0	6.9
175.24	-1.058146	1.058703	1.058424	0.920368	263.6	110.2	6.4
74.23	-1.047577	1.046913	1.047245	0.910648	-316.0	104.6	5.7
122.83	-1.052575	1.052428	1.052502	0.915219	-69.8	103.8	5.1
148.64	-1.055280	1.055470	1.055374	0.917717	90.0	105.6	6.2
176.22	-1.058223	1.058833	1.058528	0.920459	288.3	109.6	7.2

TABLE 1

ACCELEROMETER S/N 0657

PARAMETER CHECH AFTER EACH STERILIZATION CYCLE - SECOND PERIOD

T(I)	V90(I)	V270(I)	SF(I)	MA/G	B(UG)	PPM/F	B(UG/F)
72.00	-1.048899	1.045737	1.047318	0.919711	-1509.3	101.6	17.2
122.36	-1.054060	1.051660	1.052859	0.915530	-1139.9	105.6	7.3
148.55	-1.056746	1.054832	1.055789	0.918077	-996.0	107.1	8.9
175.77	-1.059629	1.058359	1.058994	0.920864	-599.8	112.8	11.3
73.04	-1.047199	1.047745	1.047472	0.910845	260.4	105.9	-8.4
123.57	-1.052425	1.053512	1.052968	0.915624	515.8	104.4	5.1
148.64	-1.055025	1.056520	1.055772	0.918062	707.7	107.1	7.7
174.70	-1.057746	1.059673	1.058709	0.920617	910.2	107.9	7.8
72.68	-1.046766	1.048115	1.047441	0.910818	643.7	104.3	2.6
122.11	-1.051869	1.053829	1.052849	0.915521	930.7	105.0	5.8
148.24	-1.054560	1.056931	1.055745	0.918039	1123.3	106.1	7.4
175.71	-1.057460	1.060309	1.058825	0.920769	1345.6	100.4	8.1
72.61	-1.048513	1.046397	1.047455	0.910830	-1010.2	104.7	22.8
122.14	-1.053547	1.052174	1.052860	0.915531	-652.9	104.7	7.2
149.50	-1.056290	1.055444	1.055866	0.918145	-490.6	105.2	9.2
177.10	-1.059108	1.058880	1.058993	0.920864	-107.6	108.1	10.6
72.95	-1.047045	1.048036	1.047540	0.910904	472.0	103.7	-5.6
122.90	-1.052135	1.053723	1.052929	0.915590	754.0	103.5	5.6
148.95	-1.054810	1.056229	1.055820	0.918104	956.5	106.2	7.8
175.12	-1.057541	1.059990	1.058765	0.920666	1156.6	107.8	7.6
73.49	-1.048568	1.046610	1.047588	0.910946	-934.5	103.9	20.6
122.50	-1.053528	1.052219	1.052874	0.915542	-621.4	103.4	6.4
150.28	-1.056328	1.055539	1.055933	0.918202	-373.5	105.4	8.9
176.90	-1.058951	1.058784	1.058867	0.920754	-78.8	105.5	11.1

TABLE 2

ACCELEROMETER S/N 0660

INITIAL TESTING

T(I)	V90(I)	V270(I)	SF(I)	MA/G	B(UG)	PPM/F	B(UG/F)
72.68	-0.963078	0.962840	0.962959	0.917104	-123.6	0.0	0.0
121.71	-0.968202	0.967778	0.967993	0.921898	-222.1	107.2	-2.0
149.94	-0.971120	0.970740	0.970930	0.924605	-195.7	108.3	0.9
174.78	-0.973804	0.973408	0.973606	0.927243	-203.4	112.2	-0.3
72.68	-0.963082	0.962839	0.962960	0.917105	-126.2	107.1	-0.8
122.41	-0.968270	0.967850	0.968060	0.921961	-216.9	107.0	-1.8
149.29	-0.971090	0.970660	0.970875	0.924643	-221.4	109.1	-0.2
175.21	-0.973841	0.973408	0.973624	0.927261	-222.3	110.5	-0.0
71.02	-0.962923	0.962673	0.962798	0.916950	-120.9	106.7	-0.9
122.07	-0.968260	0.967820	0.968040	0.921943	-227.3	107.2	-1.9
149.63	-0.971139	0.970696	0.970917	0.924683	-228.1	108.7	-0.0
174.49	-0.973824	0.973380	0.973602	0.927240	-228.0	112.5	0.0
71.56	-0.962993	0.962726	0.962859	0.917009	-138.6	107.2	-0.9
123.30	-0.968372	0.967922	0.968147	0.922044	-232.4	106.7	-1.8
149.00	-0.971050	0.970624	0.970837	0.924606	-219.4	109.0	0.5
176.65	-0.973980	0.973530	0.973755	0.927386	-231.0	109.9	-0.4
73.65	-0.963197	0.962934	0.963065	0.917205	-136.6	106.6	-0.9
122.22	-0.968291	0.967807	0.968049	0.921951	-250.0	107.1	-2.3
148.59	-0.971030	0.970576	0.970803	0.924574	-233.8	108.2	0.6
174.60	-0.973808	0.973355	0.973581	0.927220	-232.6	111.3	0.0

TABLE 3

ACCELEROMETER S/N 0660

PARAMETER CHECK AFTER EACH STERILIZATION CYCLE - SECOND PERIOD

T(I)	V90(I)	V270(I)	SF(I)	MA/G	B(UG)	PPM/F	B(UG/F)
71.87	-0.965750	0.960636	0.963193	0.917327	-2654.7	103.8	23.6
122.45	-0.970989	0.965760	0.968374	0.922261	-2699.9	106.9	-0.9
147.81	-0.973820	0.968568	0.971194	0.924946	-2793.9	115.8	-0.2
176.72	-0.976790	0.971654	0.974222	0.927830	-2635.9	109.0	2.4
73.18	-0.965389	0.961247	0.963318	0.917446	-2149.9	108.1	-4.7
122.22	-0.970558	0.966072	0.968315	0.922204	-2316.4	106.3	-3.4
148.82	-0.973294	0.968872	0.971083	0.924840	-2276.8	108.3	1.5
175.39	-0.976070	0.971730	0.973900	0.927523	-2228.2	110.4	1.8
72.79	-0.964544	0.962086	0.963315	0.917442	-1275.8	105.9	-9.3
122.05	-0.969713	0.966994	0.968353	0.922241	-1403.9	106.7	-2.6
148.46	-0.972478	0.969720	0.971099	0.924856	-1429.1	108.2	-0.6
176.09	-0.975442	0.972661	0.974051	0.927668	-1427.6	111.3	-0.3
72.64	-0.965122	0.961430	0.963276	0.917406	-1916.4	106.9	4.7
122.29	-0.970350	0.966462	0.968406	0.922291	-2007.4	107.8	-1.8
148.71	-0.973146	0.969268	0.971207	0.924959	-1906.5	110.4	0.4
175.96	-0.976022	0.972240	0.974131	0.927743	-1941.[illegible]	111.7	2.0
72.97	-0.962782	0.963958	0.963370	0.917495	610.4	107.2	-24.8
122.94	-0.968114	0.968836	0.968475	0.922357	372.7	106.6	-4.8
149.00	-0.970908	0.971516	0.971212	0.924963	313.0	109.3	-2.3
175.10	-0.973708	0.974147	0.973927	0.927540	225.4	109.3	-3.4
73.49	-0.964383	0.962436	0.963409	0.917533	-1010.5	106.3	12.2
122.68	-0.969700	0.967270	0.968485	0.922366	-1254.5	107.6	-5.0
148.39	-0.972420	0.969950	0.971185	0.924938	-1271.7	109.3	-0.7
176.07	-0.975403	0.972960	0.974181	0.927792	-1253.9	112.7	0.6

TABLE 4

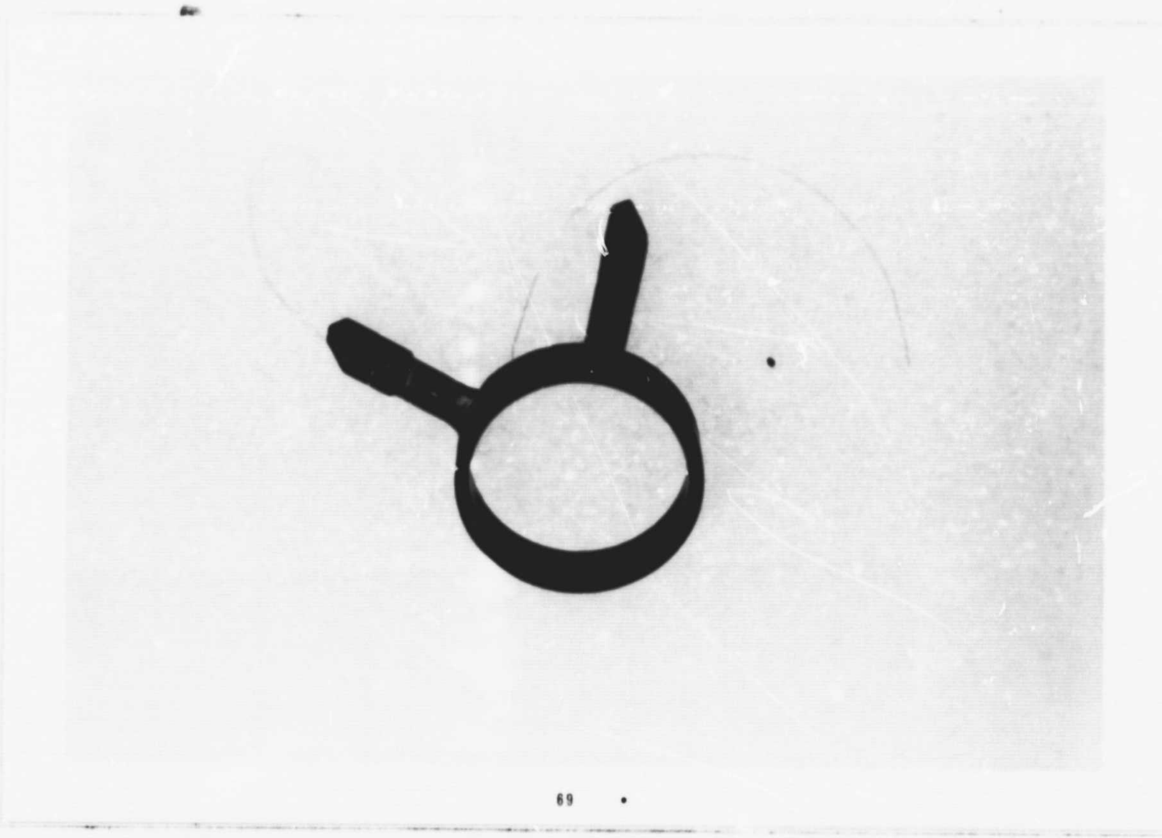


FIGURE 1. OUTER-WOUND BERYLLIUM PROOFMASS STRUCTURE

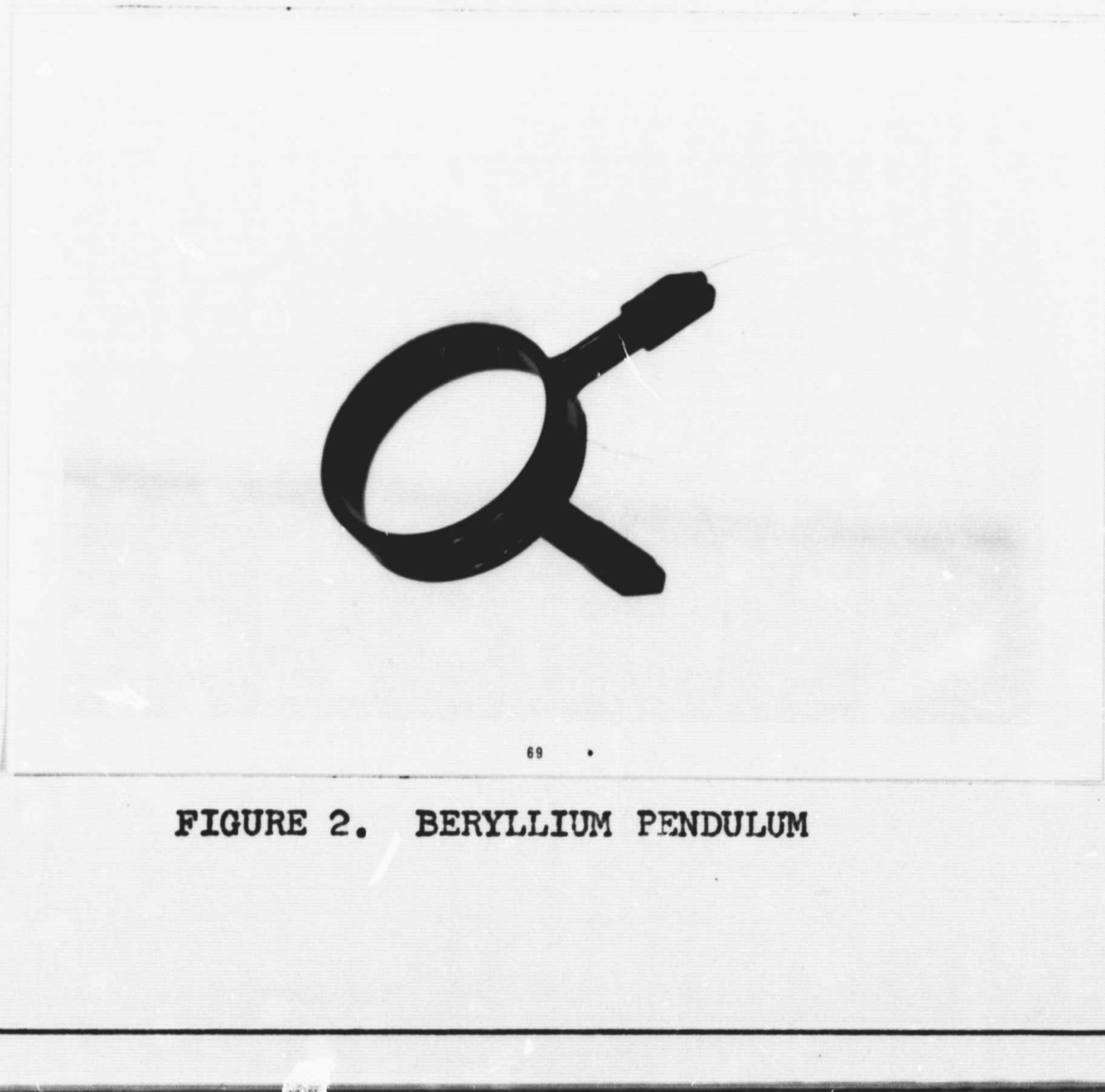


FIGURE 2. BERYLLIUM PENDULUM

LASER WELDED PENDULUMS

Two pendulums incorporating laser beam welding techniques were built and tested. These were of the design presented in the November 1968 Quarterly Report, pages 14-17. Erratic performance of unit M33 resulted in the discontinuation of its stability testing. Instrument M41 was more satisfactory and stability test data was plotted in Figures 3 and 4. Thermal sterilization was not intended for these instruments since only the practicality of a laser welded spring - support connection was the objective and standard non-sterilizable bonnets were attached.

Because of manufacturing difficulties at the time it was possible to produce only a single weld spot. Although the rigidity of the weld joint was considered higher than that of the spring, its influence is still present in the performance of units M33 and M41. Practice welds have since been successfully performed on some experimental parts and two weld spots in the areas shown in Figure 5 will be provided in the final three pendulum assemblies.

The three proofmass assemblies are being manufactured having a current sensitivity of 1 ma/g compatible with the sterilizable accelerometer. In contrast to the pendulums previously built, a wire wound torquer coil is required to obtain the desired current sensitivity. The wire is wound directly on a standard anodized coil form and the windings secured by the application of 828 "Z" epoxy in the same manner as on the sterilizable accelerometer. In order to retain the use of the springs as the current conductor to the winding, an insulating member must be introduced into the existing metal path from one spring to the other.

UNIT M41 - H79

Measurements taken at
Operating Temp. of 165°F

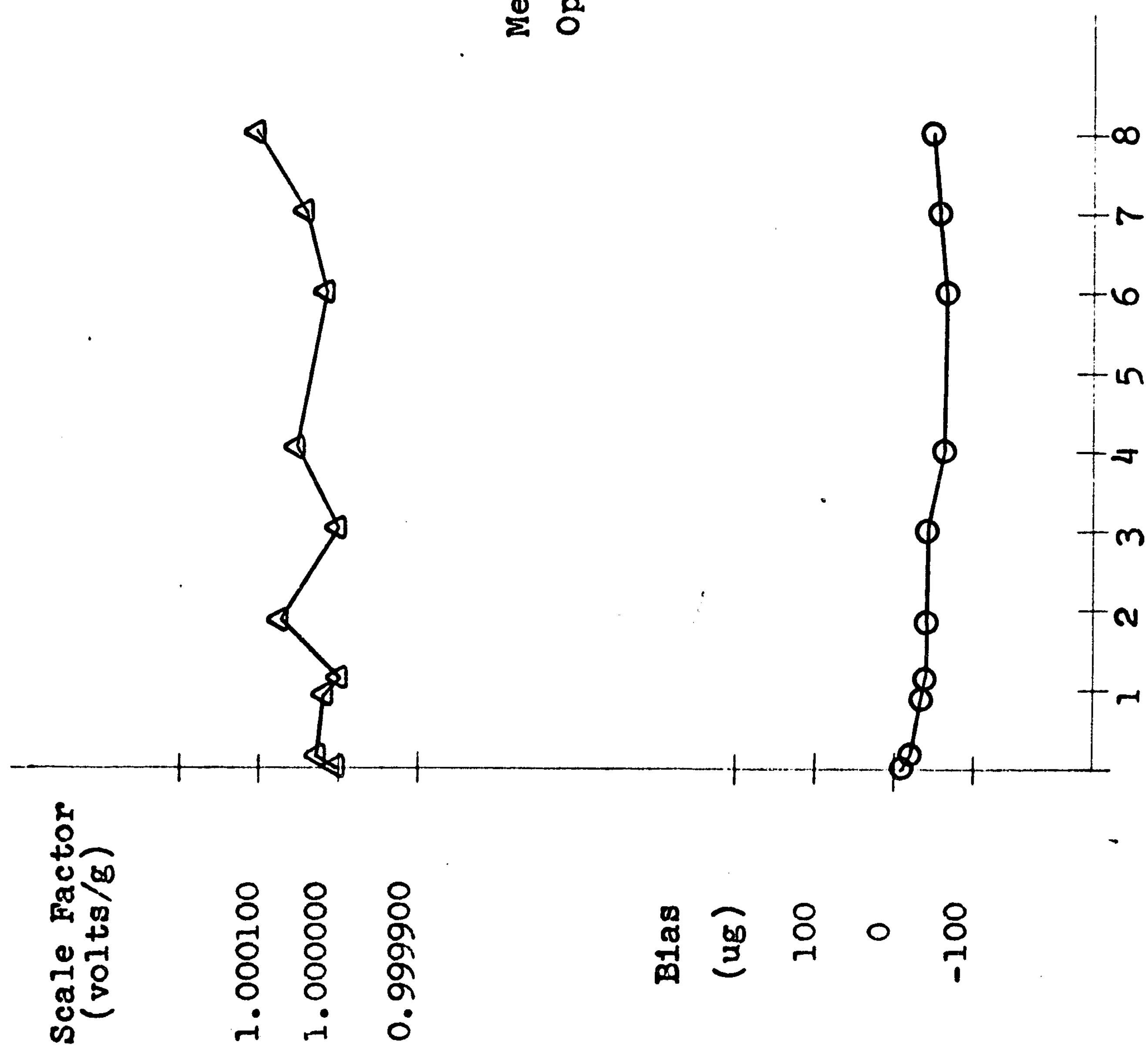
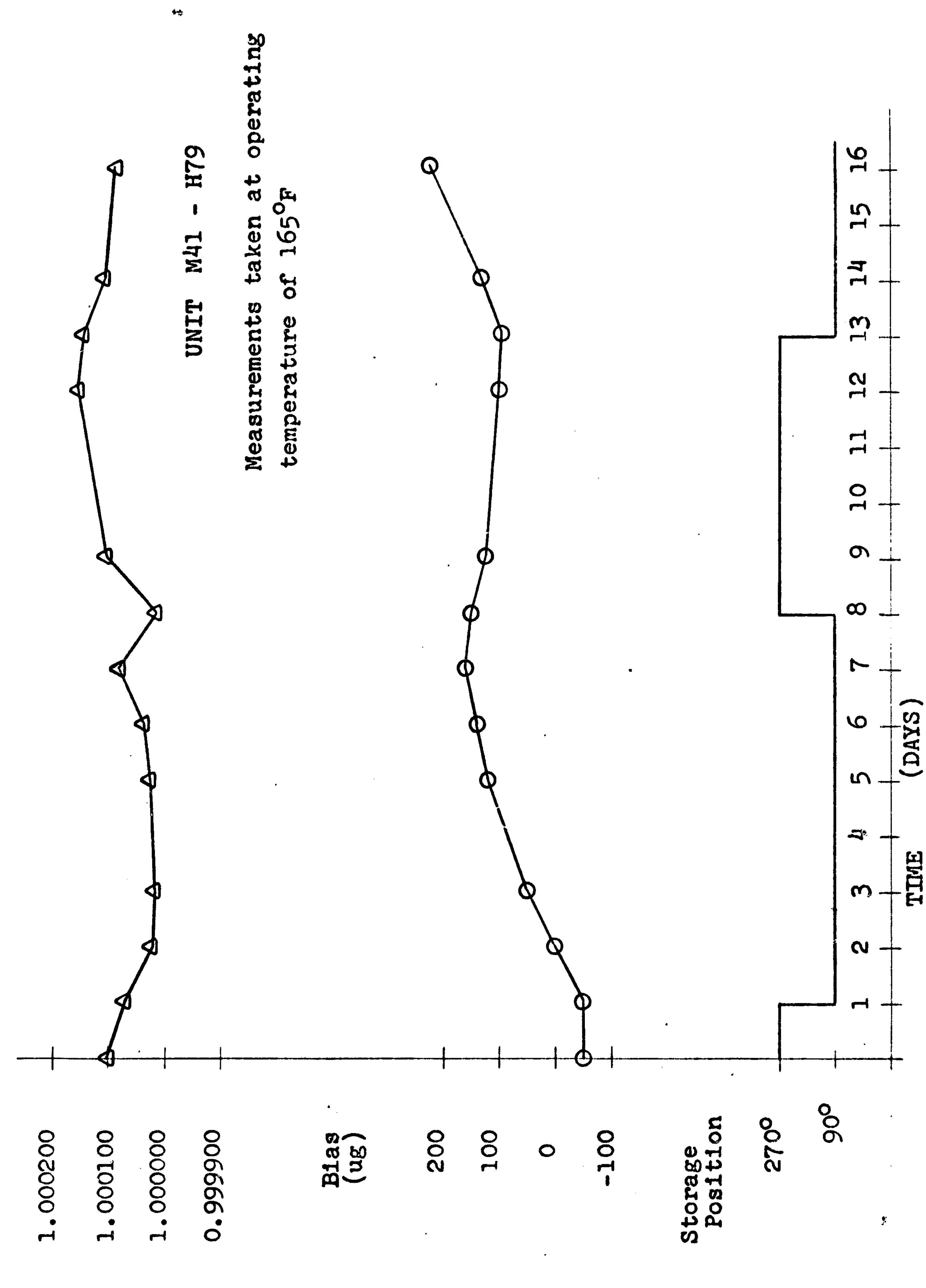


FIGURE 3. M41 STABILITY TEST

FIGURE 4. M41 Stability Testing & Positional Storage



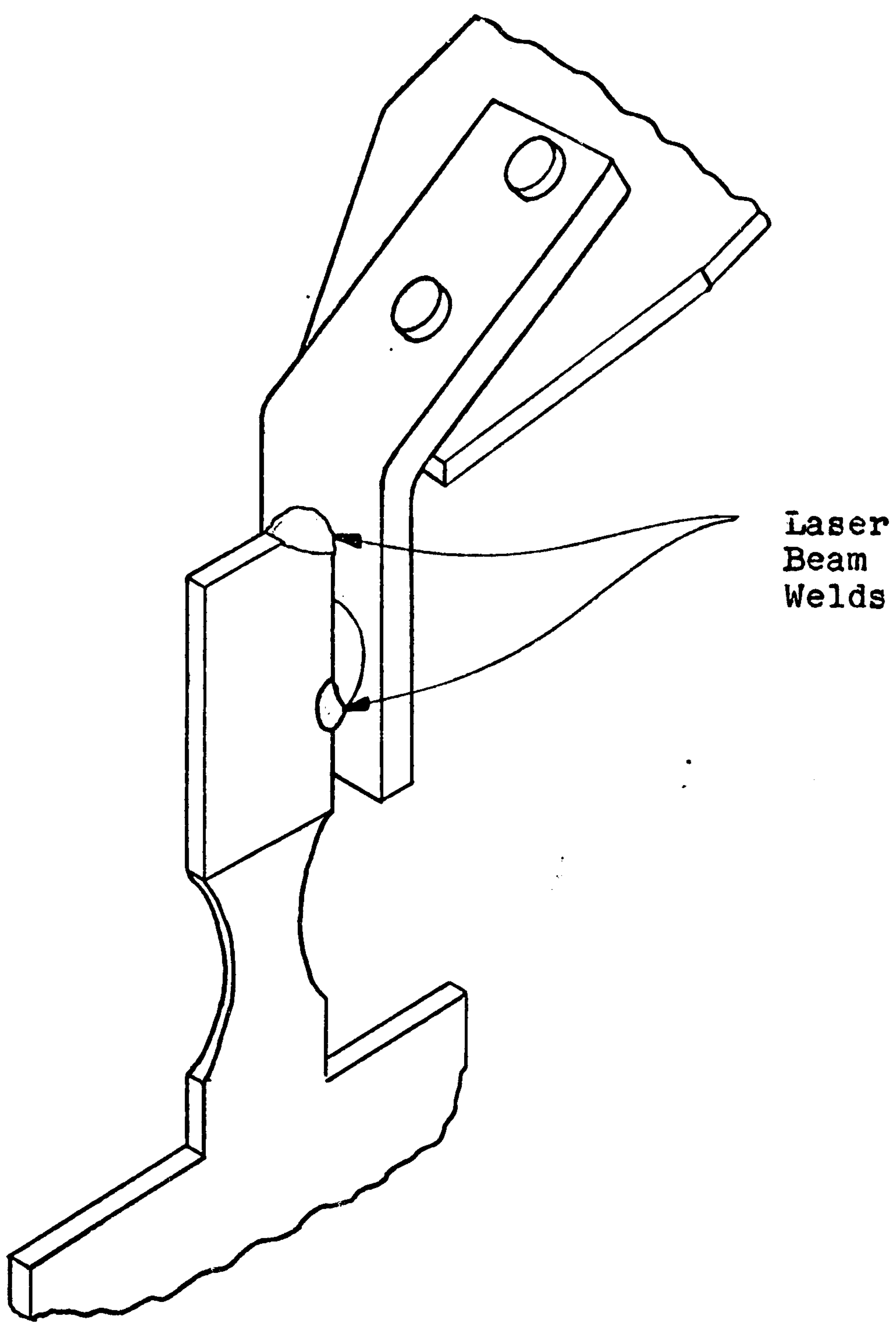


Figure 5. Location of Laser Welds

Figure 6 depicts the design employed to electrically isolate the two springs. The aluminum supports consist of two parts of which one is attached to the coil form in the usual manner of staking to the coil form and securing the joint with an epoxy fillet. This part has been hard-coat anodized .002 inch thick on the two flat surfaces. A second part is attached by means of two J.I. Morris #0000-160 brass fillester head screws and is bent to provide the mating surface for the laser weld connection. Proper surface preparation and alignment are essential for successful weldments. In this application there should be no contact between the spring and the support to assure that no stresses are on the spring prior to welding.

The non-insulated support is built from the same parts except the piece which is joined to the form coil is not hard-coat anodized. In this manner, the weight distribution is kept symmetrical and spring replacement, if needed, is simlified. Insulation resistance is maintained under a breakdown voltage of 50 volts.

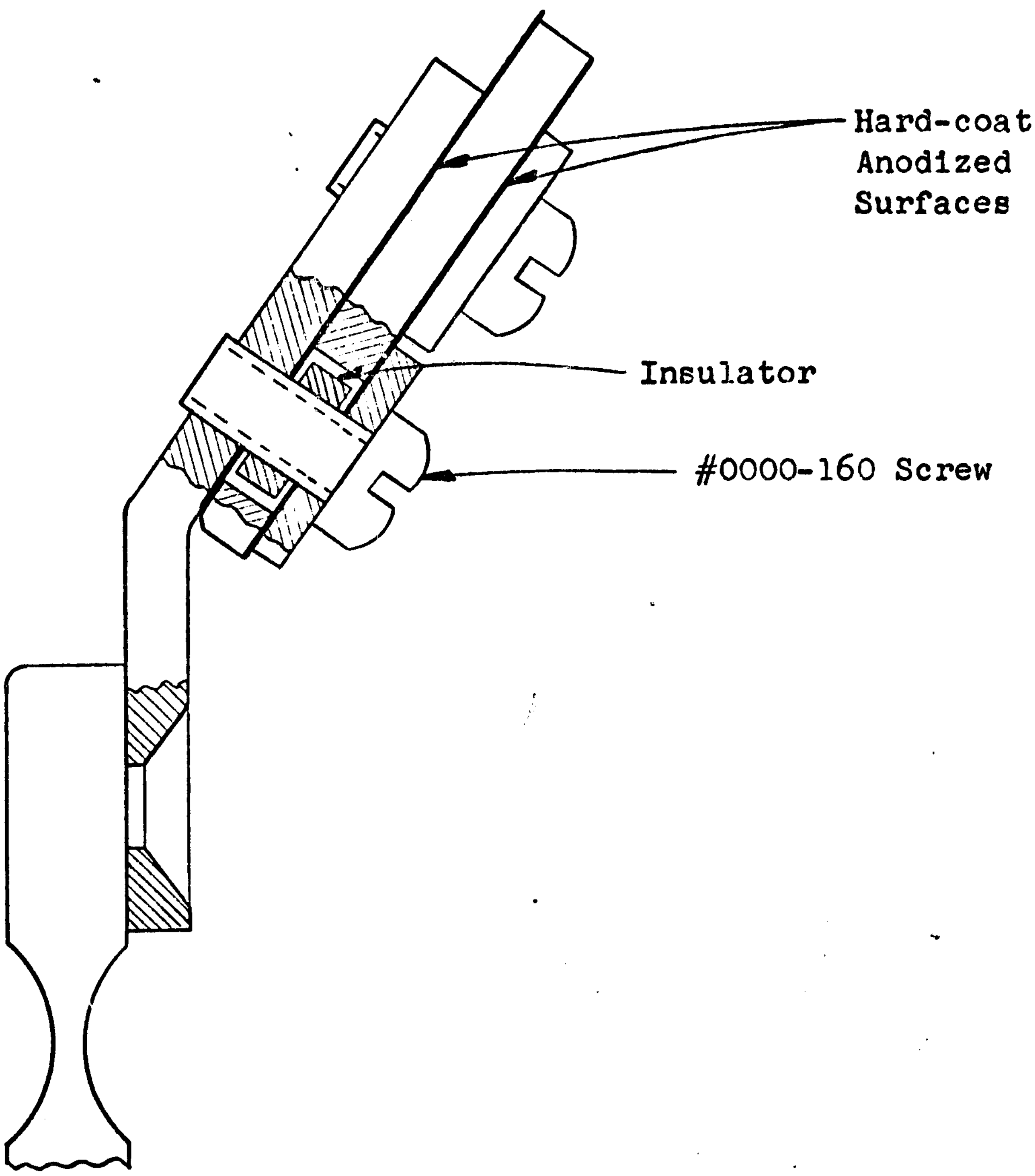


Figure 6. Construction details of insulated support for laser welded pendulum.

Figure 7. Aluminum Pendulum for Laser Welding

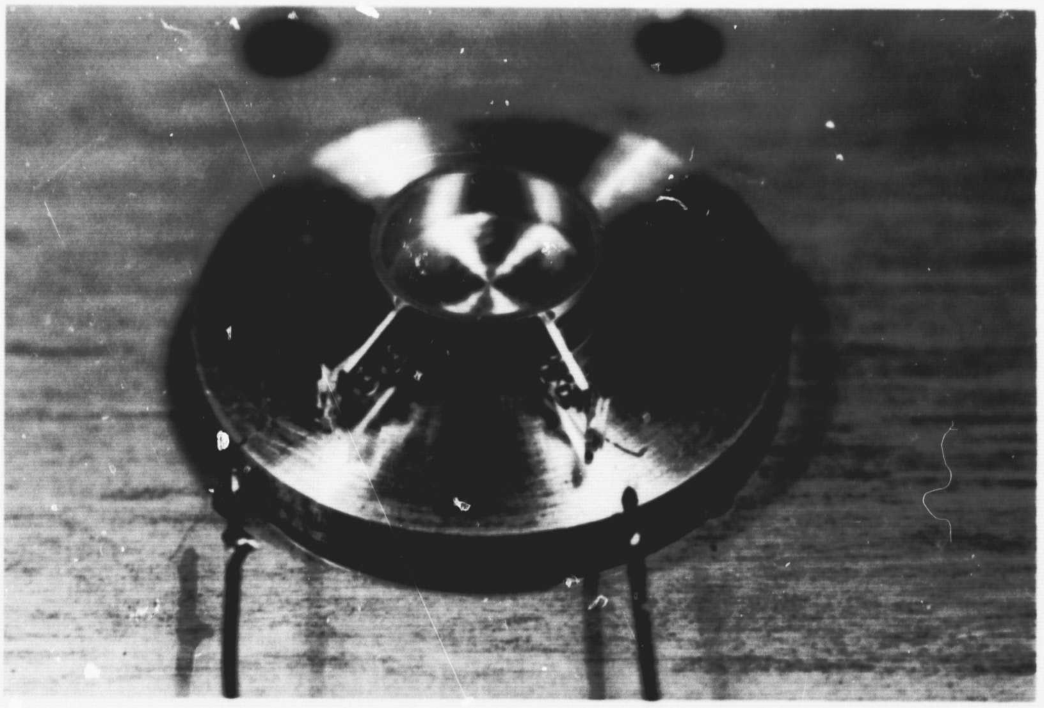


Figure 8. Aluminum Pendulum for Laser Welding

TRANSFORMERLESS ELECTRONICS

The transformerless bonnet circuit has been manufactured as a thin-film electronics on a ceramic substrate and assembled on supporting glass fiber epoxy boards. The original transformerless bridge pickoff circuit was developed utilizing discrete components and commercially available integrated circuits.

A comparison between the thin-film bonnet and a typical transformer bonnet can be seen in Figures 9 and 10. It should be noted that the null adjustment capacitor in the new electronics configuration can only be made through an access hole in the mounting base. Pin "E" of the top cover would not allow the positioning of the adjustment hole over the relocated variable capacitor. The variable was therefore inverted and the mounting base modified for adjustment from the bottom of the accelerometer. This poses no problem in the final null bias adjustment of the instrument.

Due to design, the electrical connections are different on the transformerless electronics. The schematic Figure 11, in this report identifies the new functions of the header pins.

The plan for the thermal sterilization compatibility testing of the transformerless electronics is as follows. The thin-film bonnet is to be mated to a mechanical assembly which had the torque coil assembly removed. This is done to simulate the presence of stray capacitances introduced by the mechanical sensor. They will be mounted on the previously noted specially modified mounting base. After stabilization of the instrument case temperature at 25°C (76°F), ±15 volt DC power and an oscillator signal of 1.5 vRMS at 10K HZ are applied.

The variable capacitor C_3 is to be adjusted to obtain null output measurements of RMS output and Phase shift reference to the excitation signal are to be recorded. Then the oscillator signal is to be adjusted for 1.5 vRMS at 40K HZ and RMS output and phase shift measurements will be recorded. Without adjusting the variable capacitor the oscillator signal will be readjusted for 1.5 vRMS at 10K Hz and the RMS output and phase shift readings recorded. In the thermal soak portion of the testing, temperatures will be stabilized for one hour at 50°C (122°F), 65°C (149°F), and 80°C (176°F) prior to subjection of the electronics to the sterilization temperature of 135°C (275°F). RMS output and phase shift readings are to be recorded immediately after the temperature setting changes and after thermal stabilization takes place.

Two bonnet electronics have been assembled and tested. The first transformerless bonnet was subject to a thermal soak test as shown in Figure 12. This unit was tested for approximately 3 hours total at 80°C prior to sterilization temperature test at 135°C. After the unit was tested at 135°C for 1 hour it was retested with power applied. This bonnet failed at 65°C when the output measured a +12Vdc offset. The defective bonnet was removed and the failure was investigated. Results indicated that the integrated circuit chip (uA709) failed due to contamination on the chip.

The second bonnet was assembled for testing in the same configuration as bonnet #1. The test plan was altered so that the effects of the low temp thermal soak could be determined for the integrated circuit null offset. Therefore bonnet #2 will be subjected to a longer low temp cycle than bonnet #1. Initial testing on bonnet #2 indicated a noise amplitude change from 12.6 to 8.5 mv after a 24 hour soak at 80°C.

Due to the insufficient test data available, it is premature to conclude that the transformerless bonnets can satisfactorily replace the conventional transformer pick-off electronics in a sterilizable accelerometer.

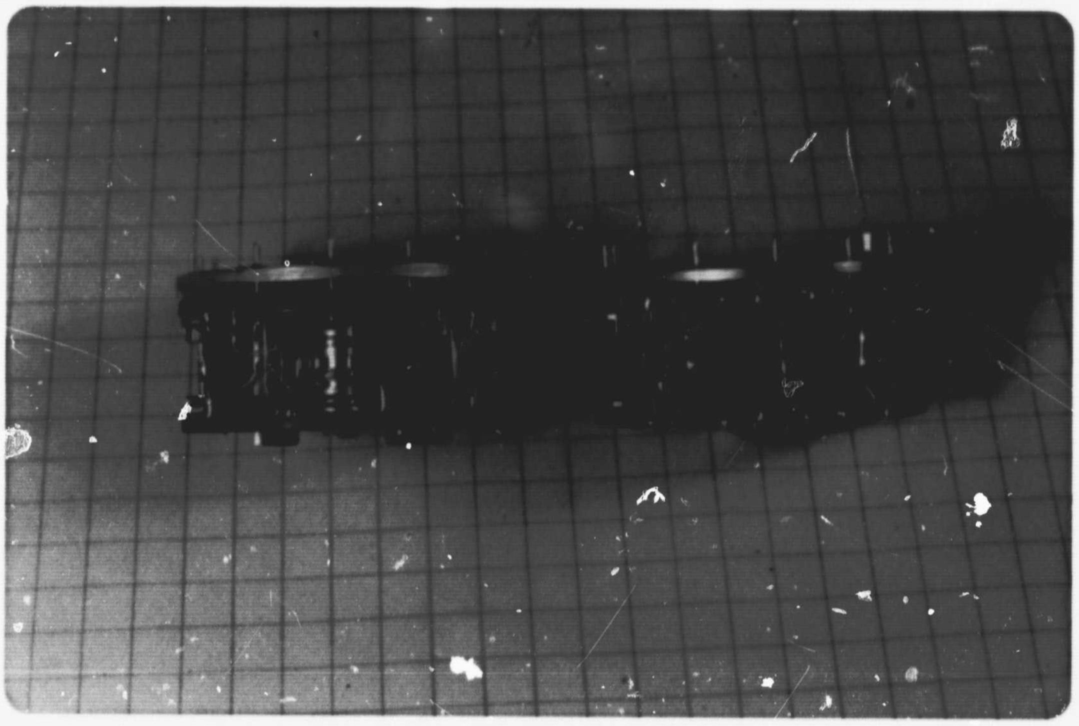


FIGURE 9. Comparison of transformerless electronics and typical transformer bonnet

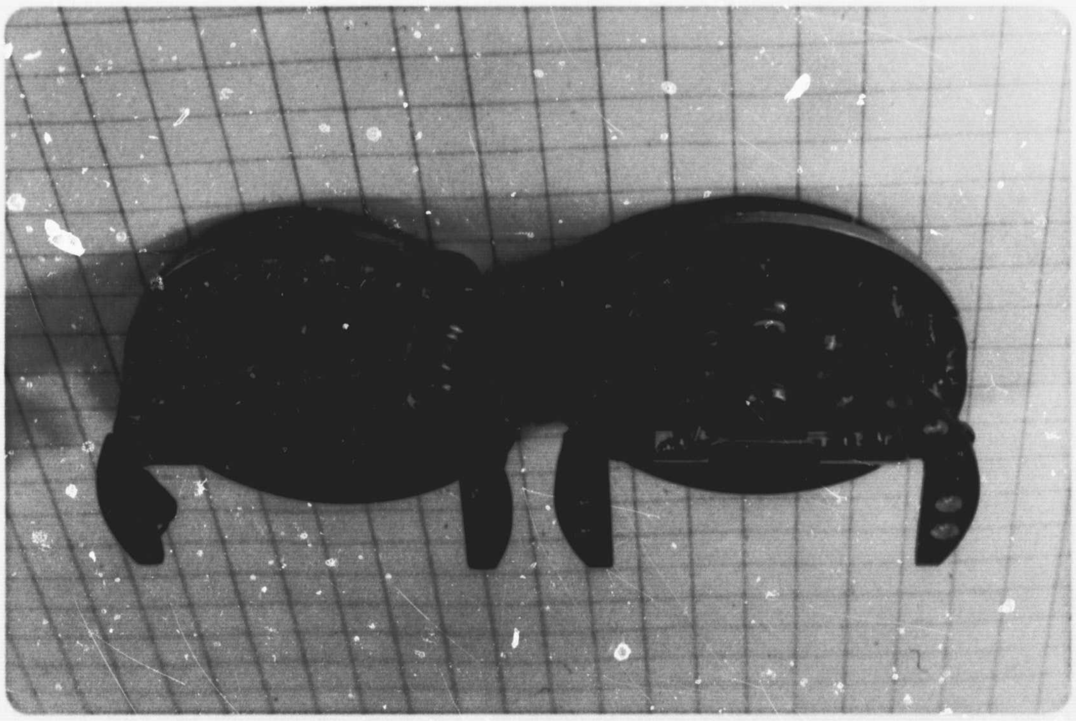


FIGURE 10. Comparison of transformerless electronics and typical transformer bonnet

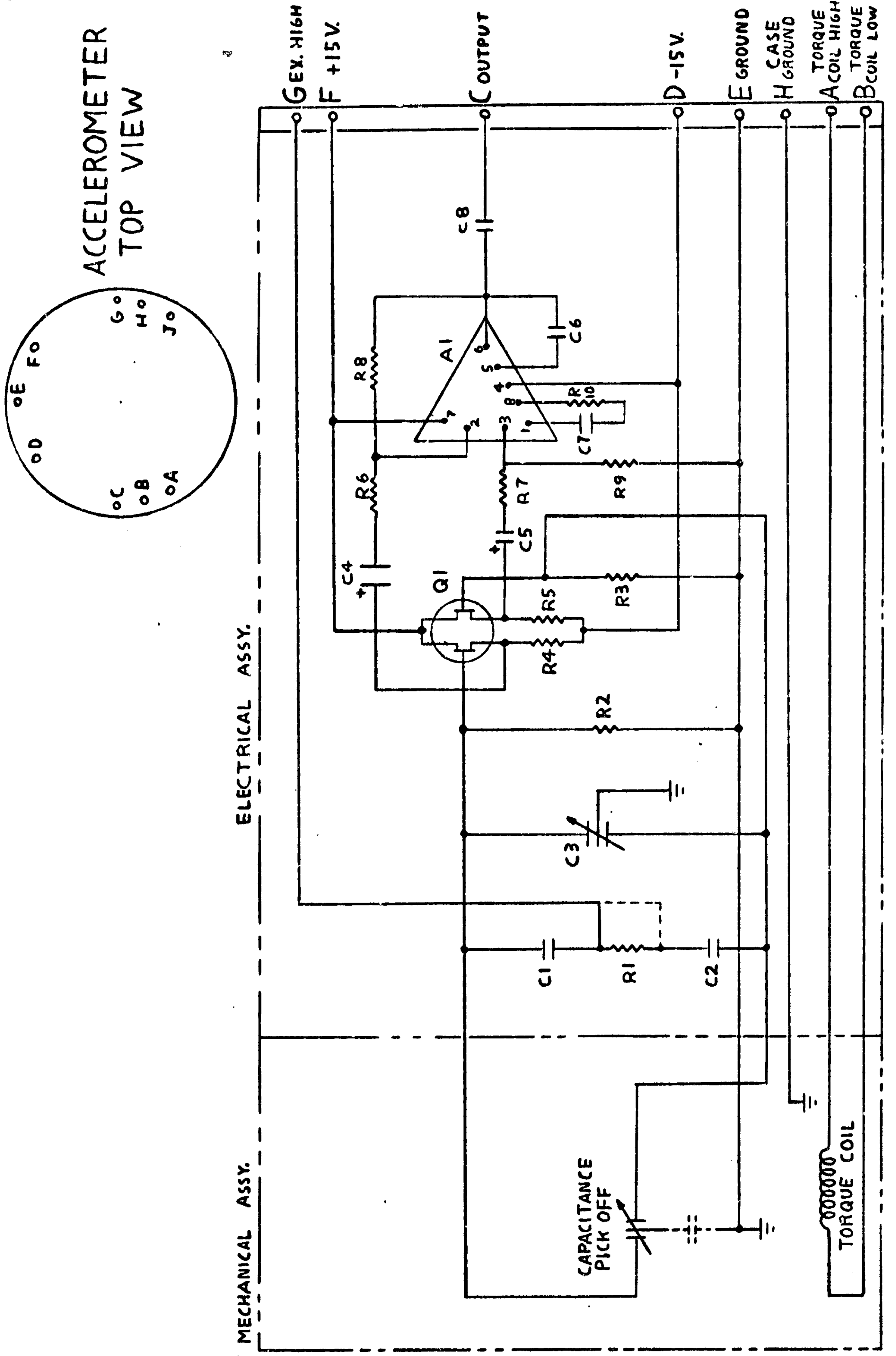

ACCELEROMETER
TOP VIEW
G EX. HIGH
F +15 V.
C OUTPUT
D -15 V.
E GROUND
H CASE GROUND
A TORQUE COIL HIGH
B TORQUE COIL LOW
ELECTRICAL ASSY.
MECHANICAL ASSY.
CAPACITANCE PICK OFF
TORQUE COIL
A1
Q1
C1
C2
C3
C4
C5
C6
C7
C8
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10

FIGURE 11

Thermal Path of first transformerless bonnet

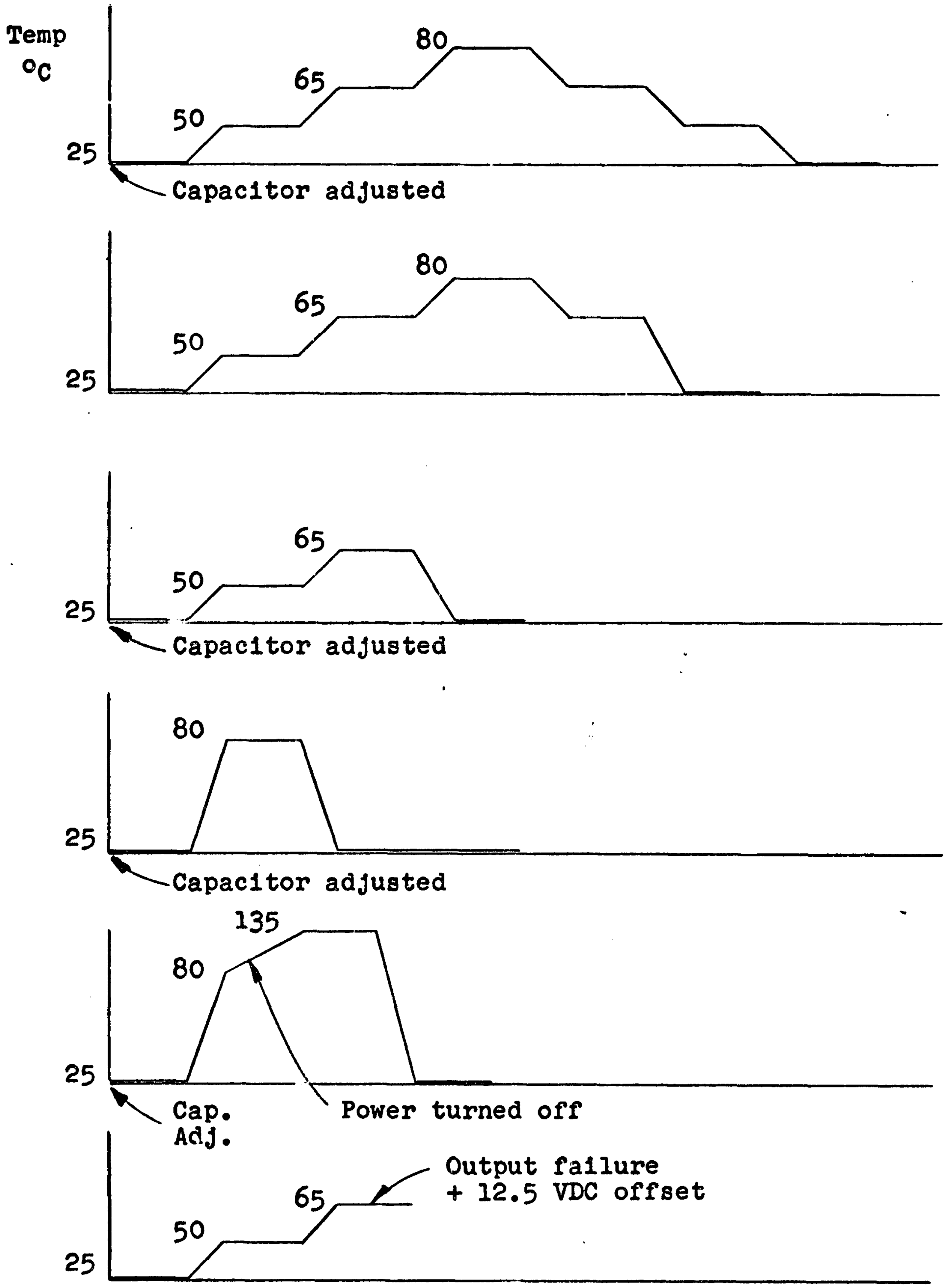


FIGURE 12